

# *The Mechanical Effects of Canal Rays.*

By A. A. CAMPBELL SWINTON.

(Communicated by Sir William Crookes, F.R.S. Received May 16,—  
Read June 6, 1907.)

This investigation was undertaken in order to discover whether the so called canal rays (Canalstrahlen) discovered by Goldstein, which, at suitable pressures, visibly stream through the apertures in a perforated cathode, backward away from the anode, share with cathode rays the property discovered, as regards the latter, by Sir William Crookes many years ago, of producing a sufficient mechanical pressure to cause small and light mica mill-wheels to rotate. Several tubes were constructed and experimented with, and all showed that canal rays do cause mica mill-wheels to rotate quite rapidly.

Fig. 1 is the form of tube with which this was most conclusively demonstrated.  $A_1$  is the anode, the lower end of which is tipped with a glass plate, so as to preclude the transmission of cathode rays vertically downwards in the event of this electrode acquiring at any moment a negative charge due to oscillations in the electric discharge.

$A_2$  is a supplemental anode, added since the paper was communicated, and referred to in the addendum.

$C$  is the perforated cathode of aluminium, which is compound, consisting of  $C_1$  of the cathode proper, perforated with six apertures.  $C_2$  is a similar plate correspondingly perforated, and  $C_3$  a third plate or shutter of aluminium also correspondingly perforated, loosely pivoted on a central pin between  $C_1$  and  $C_2$ , and furnished with an armature  $D$  of soft iron, so that by means of a magnet it can be slightly rotated so as to open or close simultaneously all the six apertures. A plan view of the shutter and armature is shown in Fig. 2.

It was found advisable to make  $C_1$ ,  $C_3$ , and especially  $C_2$  of thick plate, so as to avoid thermal effects.

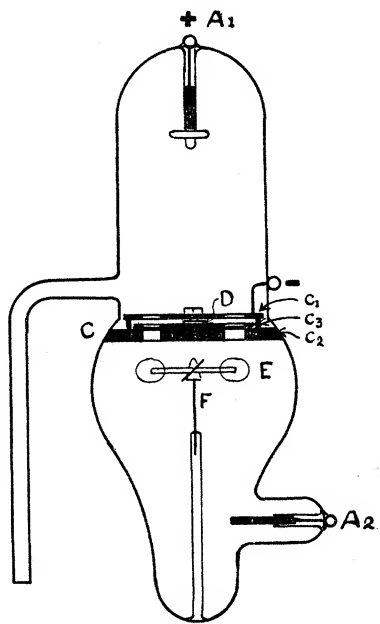


FIG. 1.

E is the mill-wheel of the screw propeller form, with mica vanes set at an oblique angle to the axis, mounted on a pivot F. The complete mill-wheel weighs about 0.19 gramme.

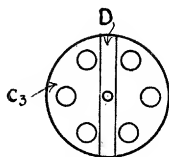


FIG. 2.

The experiments were conducted with the tube connected to a vacuum pump, so that the pressure could be regulated as desired. An induction coil was employed to produce the electrical discharge, a spark-gap being usually inserted in the circuit, with a view to obtaining currents

only in one direction.

Rapid rotation of the mill-wheel, in the direction that would indicate that the canal rays consist of particles travelling away from the cathode, was easily obtained in all cases, the best results being got with medium vacua, when the canal rays were highly luminous.

That the effect was due to the action of the canal rays, was tested in several ways. Firstly, the shutter  $C_3$  was rotated until all the apertures were closed. Under these conditions no rotation could be obtained, whereas when the apertures were open the mill-wheel was found to commence rotation the moment the current was turned on.

Again, the current was reversed and A made cathode in order to observe whether cathode rays from A might not be the cause of the rotation. This was found not to be the case. The upper part of the tube was also placed in a strong magnetic field, so as to deflect on to the walls of the tube any cathode rays reflected from the upper end of the tube, which, it was thought, might cause the rotation. As the motion was in no ways affected by the deflection of these reflected rays, it was obvious that the effect was not due to them.

It seems, therefore, clear that the rotation of the mill-wheel is caused by the canal rays impinging on the vanes of the former, though it appeared very probable that the effect was a secondary one, due to the rays making the vanes hotter on one side than on the other, with a consequent radiometer action, as is put forward by Professor J. J. Thomson,\* as the true explanation of the rotation of mill-wheels under cathode ray bombardment.

This question of difference of temperatures on the two sides of the vanes of the mica mill-wheel was therefore investigated in a special tube, in which a small piece of mica furnished with two thermo-junctions of Constantan-copper, one on each side of the mica, arranged so as to oppose their E.M.F.'s, and connected to a mirror galvanometer, was placed behind the aperture in a perforated cathode, so as to be impinged upon by canal rays. Experiments

\* 'Conduction of Electricity through Gases,' by J. J. Thomson, Second Edition, 1906, p. 629.

with this apparatus showed that the side of the mica vane struck by the canal rays was very much hotter than the other side, the difference in temperatures amounting to as much as 200° F. when the pressure was suitable.

It was also found that a maximum difference of temperature was obtained at those pressures which gave a maximum luminosity in the canal rays, which, as already mentioned, is the condition where the most rapid motion is imparted to the mill-wheel.

It thus appears that canal rays produce very similar mechanical effects as cathode rays, and in this connection the writer would draw attention to the experiment shown by Sir William Crookes, in 1891,\* and the results obtained by the writer in 1898,† which show that mica mill-wheels, while rotating in one direction under the impact of cathode rays, revolve in the opposite direction if so placed in the tube so as to be just outside the cathode stream.

The canal rays are supposed to be streams of positively electrified particles which, travelling towards the cathode, pass through the apertures in the latter, and emerge on the other side. These mill-wheels would appear to demonstrate the motion of these particles, both when they are approaching the cathode, and after they have passed through the latter.

The writer is indebted to the assistance of Mr. J. C. M. Stanton and Mr. R. C. Pierce in carrying out the experiments.

[*Addendum*, June 6, 1907.—Since the above paper was communicated, further investigations have been conducted by the writer, all of which confirm the fact that canal rays do produce marked mechanical effects.

In the tube illustrated in fig. 3, A is the anode and C the aluminium cathode, with a single perforation which allows the canal rays to impinge on the mica vanes of the mill-wheel E, which is of the water-wheel type having vanes with their surfaces in radial planes parallel with the axis. This arrangement was found to be very effective, the mill-wheel rotating rapidly at suitable vacua in the direction indicated by the arrow, which is that which one would expect from canal ray bombardment.

An exactly similar tube, but fitted with a mill-wheel entirely constructed of aluminium, the vanes being of foil about 0.0127 mm. in thickness, gave exactly similar results, except that it appeared to require rather more power to make it work.

The tube illustrated in figs. 1 and 2 was also fitted with an additional

\* "Electricity *in transitu* from Plenum to Vacuum," 'Journal of the Institution of Electrical Engineers,' vol. 20, No. 91, p. 25.

† 'Phil. Mag.,' October, 1898.

anode  $A_2$ . When this was employed in substitution for  $A_1$ , the mill-wheel was obviously subjected to the influence both of cathode rays proceeding from the cathode  $C$ , and also to the influence of canal rays streaming towards the cathode in the opposite direction.

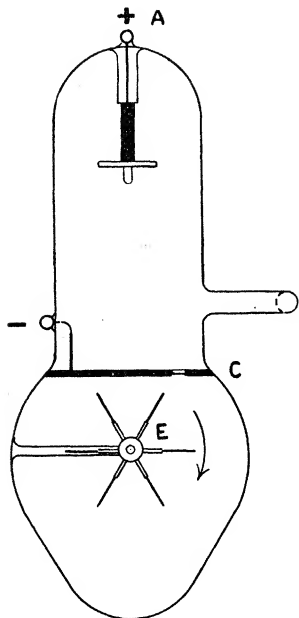


FIG. 3.

With this tube, with a mill-wheel with mica vanes, the cathode rays apparently had the more powerful effect, as both when the apertures in the cathode were open and also when they were closed the mill-wheel rotated invariably in the direction that corresponds with the motion being due to the cathode rays.

Another tube made according to figs. 1 and 2, but with the upper surfaces of the mica vanes of its mill-wheel coated with chloride of lithium, a salt which gives red fluorescence under canal ray bombardment, and blue fluorescence when the bombardment is by cathode rays, was also used. With this tube, when  $A_1$  was anode, with the apertures in the cathode open, the wheel revolved and fluoresced red under the influence of the canal rays, while with  $A_2$  as anode, the wheel turned in the same direction, but fluoresced blue under the bombardment of the cathode rays.

A further tube, constructed exactly as that illustrated in figs. 1 and 2, but with the mill-wheel and its vanes entirely constructed of aluminium foil about 0.0127 mm. in thickness and weighing altogether about 0.12 gramme, gave in one case different results. Using  $A_1$  as anode, the rotation of the mill-wheel, when the apertures were open, was the same as that of the mill-wheel with mica vanes, being in the direction that would indicate that the effect was due to the canal rays; but when  $A_2$  was made anode, the aluminium mill-wheel, instead of rotating as did the wheel with mica vanes in the direction that would correspond with the effect being due to cathode ray bombardment, was found to rotate with remarkable energy in the reverse direction, as would be caused by the canal rays proceeding towards the cathode. This was the case equally whether the apertures in the cathode were open or shut, the inference being that the force acting on the wheel due to positive particles approaching the cathode was in this case much greater than the force in the opposite direction due to the cathode ray corpuscles leaving the cathode.

In order to elucidate this divergence in the effect produced under as nearly as practicable similar circumstances upon mica mill-wheels on the one hand, and aluminium wheels on the other, further research seems necessary, but it would appear very probable that the heat insulating properties of mica, which would enable the two sides of a vane of this material to remain at widely different temperatures, and the high conductivity of aluminium for heat, which would not allow of such temperature differences, have an important bearing on this question.]

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*The Distribution of Blue and Violet Light in the Corona on August 30, 1905, as derived from Photographs taken at Kalaa-es-Senam, Tunisia.*

By Dr. L. BECKER, Professor of Astronomy, University of Glasgow.

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(Abstract.)

Nine photographs of the corona are available for discussion. They were all taken with the same instrument on the same plate (the two halves of a whole plate placed end to end) and developed in the same tray. A strong developer was used so as to produce as much contrast as possible. The plate had been exposed and moved onwards 1 or 2 inches after each exposure by an automatic device governed by a pendulum clock which closed and opened two electric circuits at specified intervals. The operator merely started the pendulum of the clock at the beginning of totality and the photographs were taken without further interference on his part. There are five exposures of 0·85 second, and one each of 9, 3, 89, 21, and 46 seconds duration. Owing to damage done in transit to the mechanism which propels the plate, the 3 seconds' exposure is partly superposed on the images belonging to those of 9 seconds and 89 seconds, with the result that only the sum of the exposures belonging to these two photographs is accurately known. This failure has somewhat complicated the reduction of the plates. During the first four exposures of 0·85 second the aperture of the lens was reduced respectively to 0·05, 0·09, 0·2, 0·4, of its area by screens, each of which had 13 equal openings distributed over the area of the lens. The effect due to diffraction produced by the screens is investigated in the